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Influence of Variable Alumina and Silica on the Relative Viscosity of a Porcelain Glaze

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INFLUENCE OF VARIABLE ALUMINA AND SILICA ON THE RELATIVE VISCOSITY OF A PORCELAIN GLAZE

BY

SIDNEY ISAAC SEWELL

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

CERAMIC ENGINEERING

COLLEGE OF LIBERAL ARTS AND SCIENCES

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Sidney Isaac Sewell

ENTITLED Influence of Variable Alumina and Silica on The Relative Viscosity of a Porcelain Glaze

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Ceramic Engineering

R. J. Stull
Instructor in Charge

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Influence of Variable Silica and Alumina on the Relative Viscosity of a Porcelain Glaze.

- Introduction -

This work was undertaken for the purpose of obtaining some data on the relation of the quantities of alumina and silica present to the viscosity and softening point of a porcelain glaze. The effect of variable alumina and silica upon the deformation temperatures of porcelain glazes has been studied by Walker[1] and by Stull and Howat.[2] In both these investigations the deformation temperatures were determined on samples moulded in cone form and fused in an electric furnace. This method is used for measuring approximate temperatures by what are known as Seger cones. In reality, it is partially a measure of combined fusion and viscosity. It gives an arbitrary idea of the relative softening temperatures, but does not give any clue to the change in viscosity due to change in composition.

In order to obtain a relative comparison of viscosity due to variable composition and variable temperature, an apparatus was arranged similar to one used by Day[3] in testing the effect

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1. "Thermal Study of Porcelain Glazes", F. W. Walker,Jr., 1911 A thesis for the B. S. degree in Ceramic Engineering.

2. "Deformation Temperatures of Some Porcelain Glazes", R. T. Stull and W. L. Howat, Vol. XVI, Trans. Am. Cer. Soc.

3. "Devitrification of Glasses", P. W. Day, 1913, A thesis for the B. S. degree in Chemical Engineering.

of alumina upon the viscosity and rate of fusion of glasses. Day found that increase of alumina lowered the softening temperature and increased the viscosity range of the glass.

Since common glasses and porcelain glazes contain similar components, it seemed plausible to predict that variable alumina would exercise a similar effect upon a porcelain glaze.

-Experimental Work-

In order to obtain some data on the point in question, a group of porcelain glazes was made covering the limits:

$$\left.\begin{matrix}.3\ K_2O \\ \\ .7\ CaO\end{matrix}\right) \quad .3 \text{ to } 1.0\ Al_2O_3 \quad \left(\begin{matrix} \\ \\ \end{matrix}\right. \quad 1.8 \text{ to } 6.0\ SiO_2$$

The glazes were made by blending the four extremes A-1, A-8, H-1, and H-8 according to their combining weights.

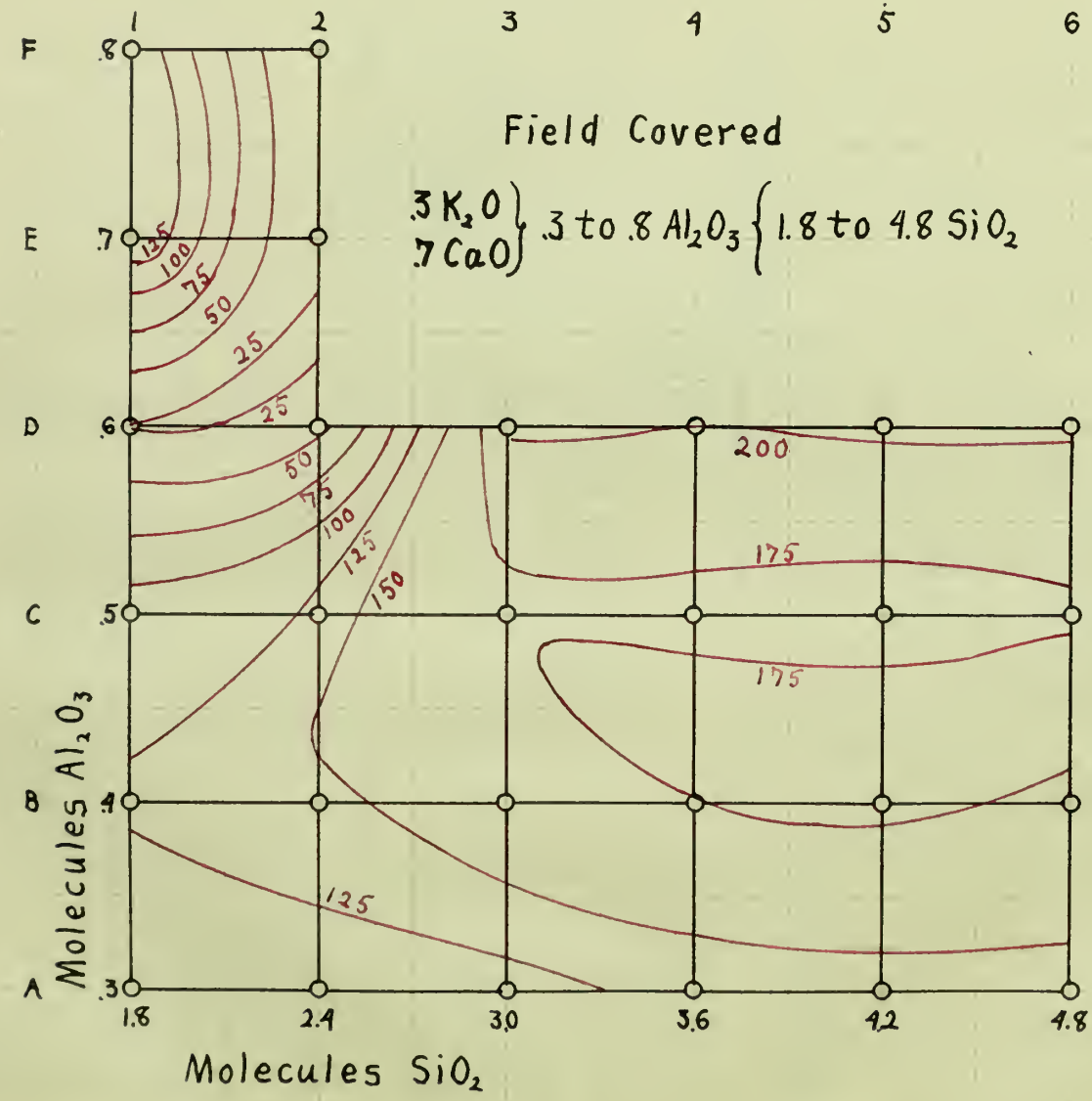
-Formulae-

Glaze	K_2O	CaO	Al_2O_3	SiO_2
A-1	0.3	0.7	0.3	1.8
A-8	0.3	0.7	0.3	6.0
H-1	0.3	0.7	1.0	1.8
H-8	0.3	0.7	1.0	6.0

-Batch Weights-

Glaze	Potash Feldspar	Whiting	Eng. C.C. No. 7	Tenn.B.C. No. 7	$Al_2(OH)_6$	Flint
A-1	167.1	70.0	-	-	-	-
A-8	167.1	70.0	-	-	-	252.0
H-1	167.1	70.0	-	-	109.2	-
H-8	167.1	70.0	90.3	90.3	-	168.0

Chart I



Iso-Viscosity lines measured by the penetration methed. The number of degrees between when the needle began to sink, and when it had reached a depth of 18 mm. is marked on each line.

The four extremes were ground wet in a ball mill and blended by weight. Each glaze was dried and powdered, after which it was placed in a battersea crucible and fused in a pot furnace in order to produce a more homogenous mixture. The resulting fused mass was broken up and powdered in a porcelain mortar. Owing to lack of time, only part of the glazes were investigated. The field covered is shown on Chart I.

The changes in viscosity of the glazes were determined by observing the rate at which a cylindrical platinum stirring rod, 2.05 millimeters in diameter, and weighing 10.4530 grams, would penetrate into the glaze when the temperature was raised at a definite rate. The time-temperature curve followed is shown on Chart II.

The glazes were fused in porcelain crucibles cast from the following mix, and burned to cone 13:

30 parts N. C. Kaolin
10 " Georgia "
10 " Tenn. Ball Clay
18 " Potash Spar
32 " Ohio Flint
½% Soda

The glazes were tested as follows: a sample of powdered glaze, previously fused in the pot furnace, was placed in a porcelain crucible and heated in the electric furnace until it fused to a clear fluid. Then the temperature was lowered to 700°C., at which the glaze became rigid. The platinum needle was lowered to the surface of the glaze, and the temperature increased at

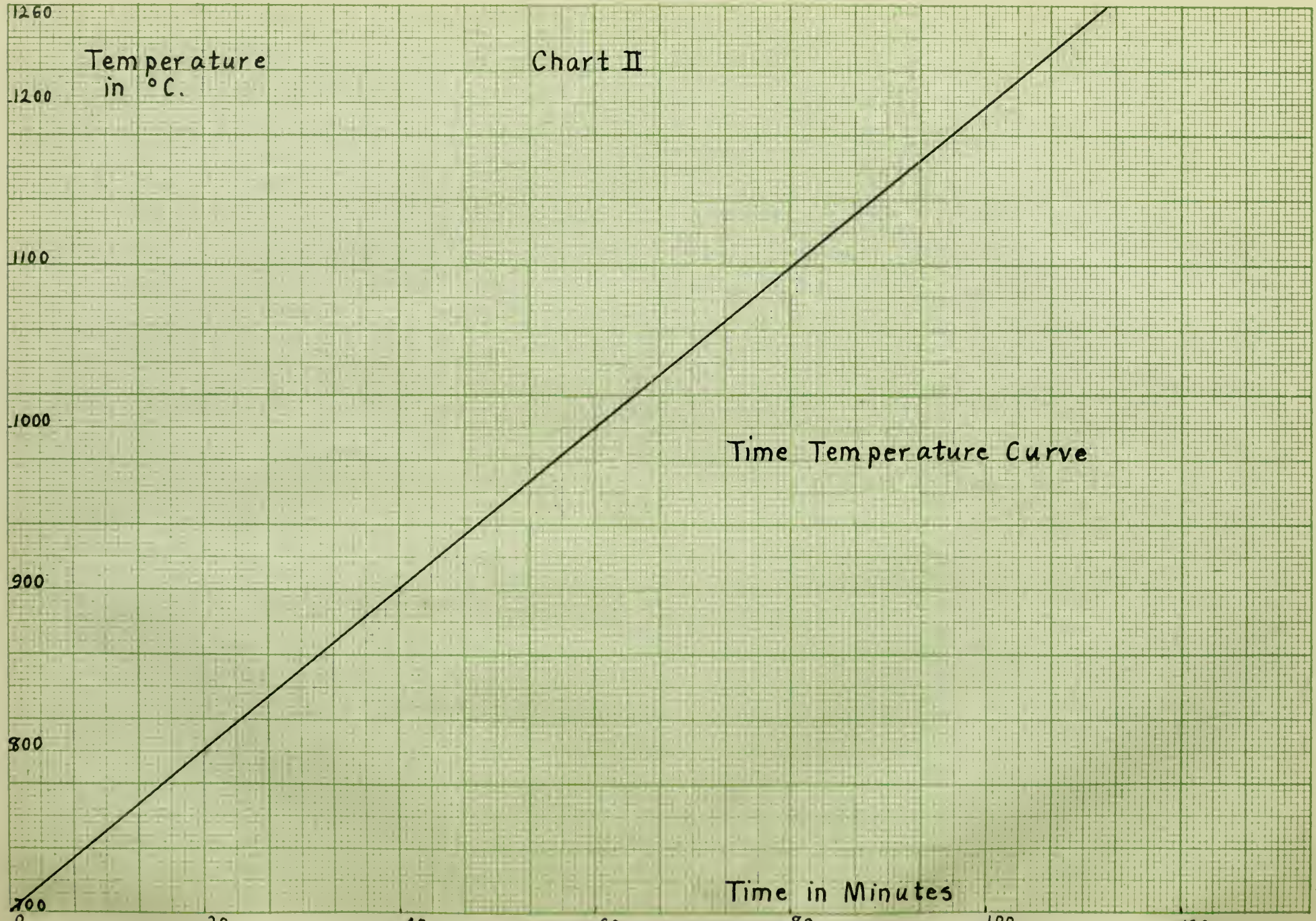
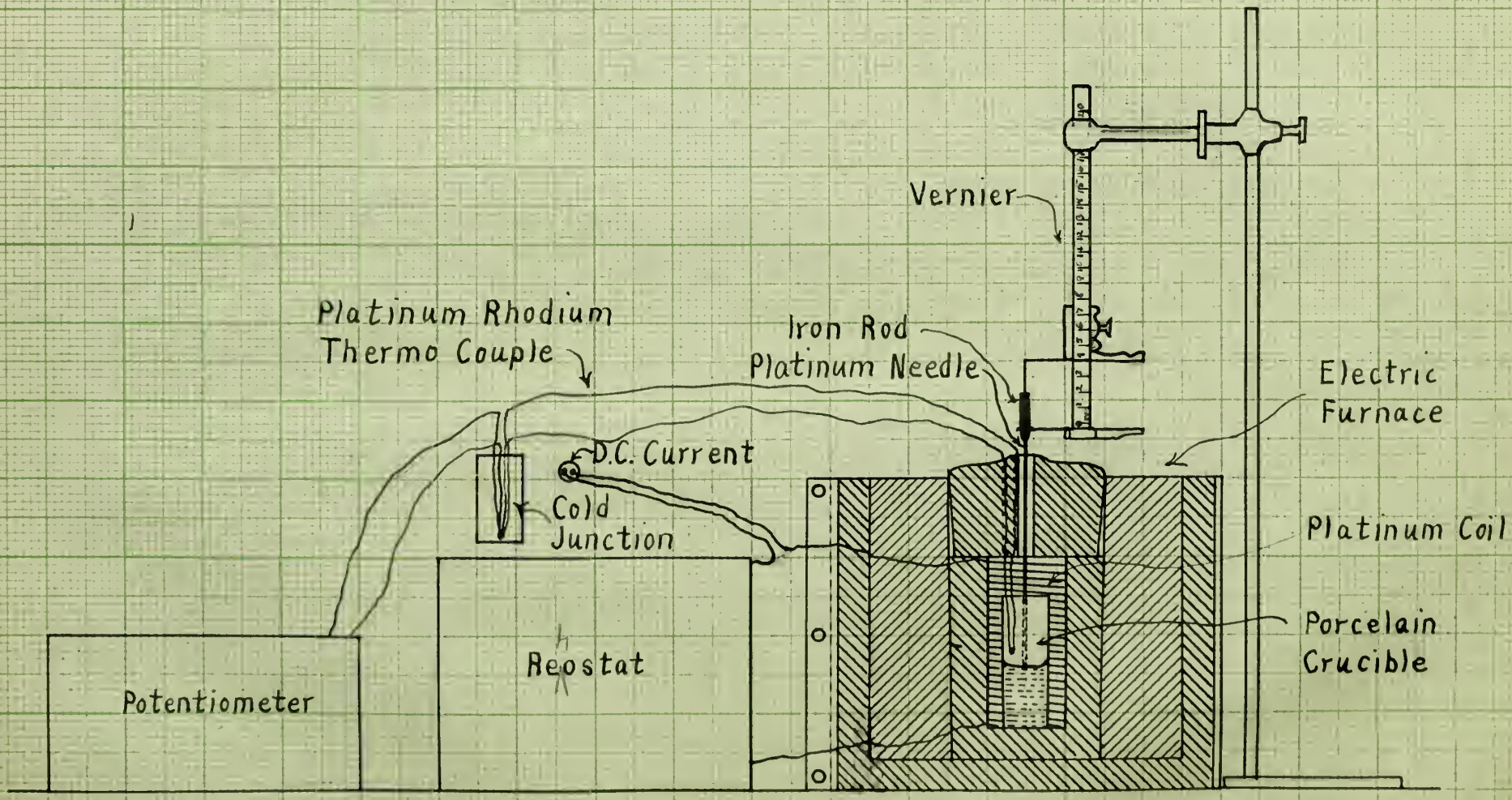

Temperature in °C.
Chart II
1260
1200
1100
1000
900
800
700
Time Temperature Curve
0
20
40
60
80
100
120
Time in Minutes

Chart III

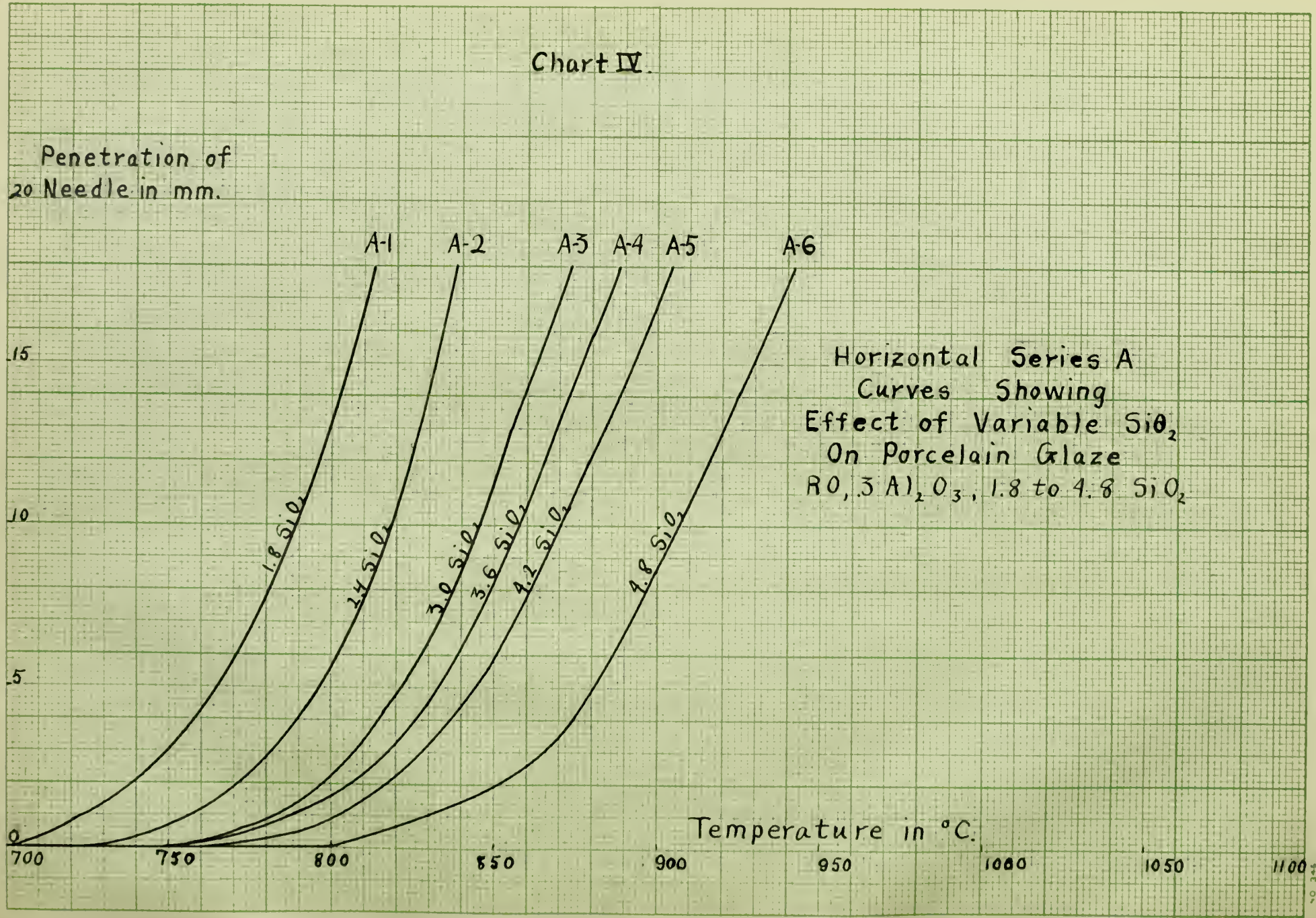
Diagram of Apparatus.



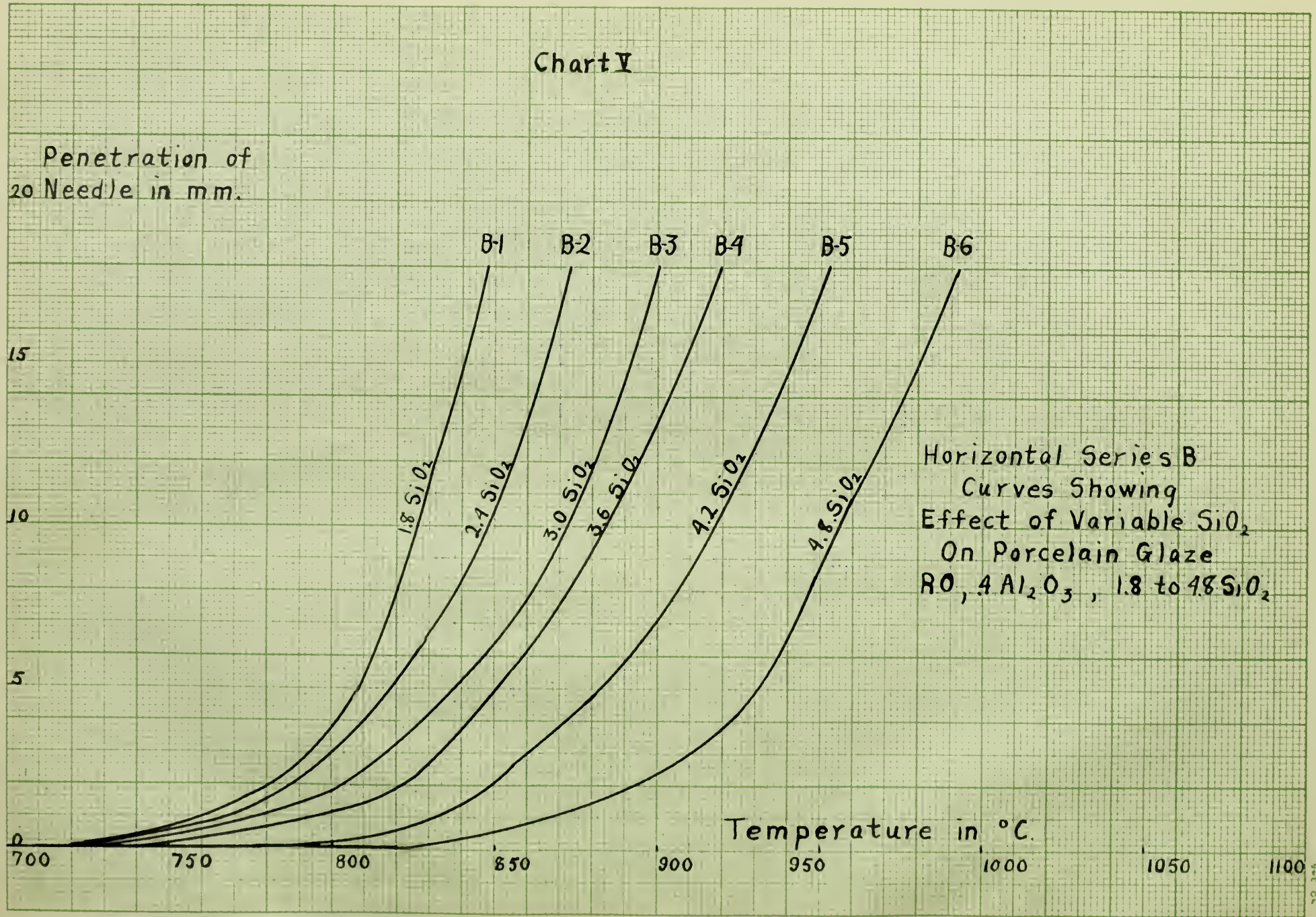
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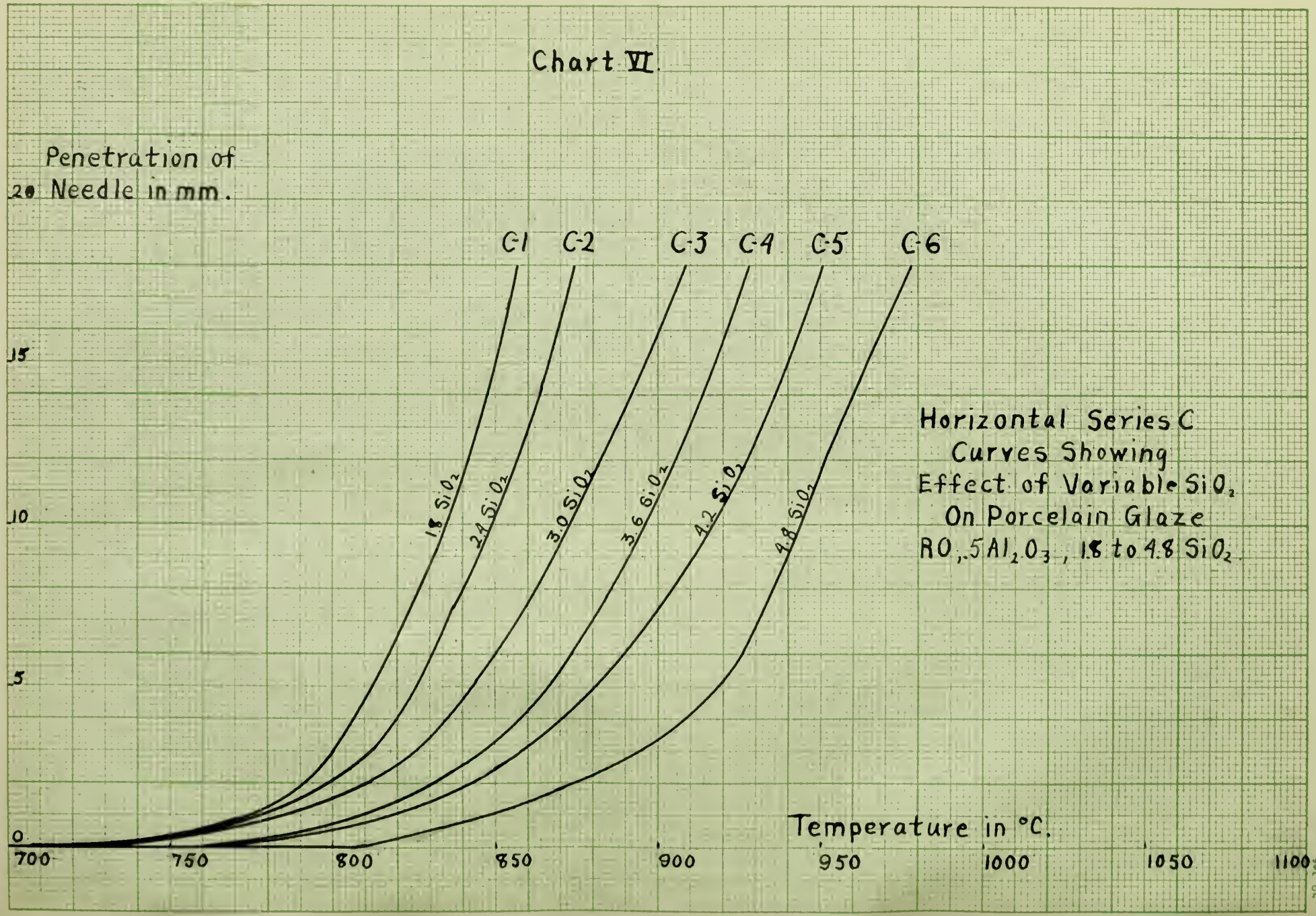
the rate of five degrees per minute. The penetration of the needle was measured on the vernier, observations being taken at intervals during the rise in temperature. A diagram of the apparatus is shown on Chart III. It consisted of a platinum coil electric furnace which was connected with a D. C. current controlled by a rheostat. The temperature was measured by means of a platinum-rhodium thermocouple, extending into the furnace just above the melt, the readings being taken by a Leeds-Northrup direct reading potentiometer.

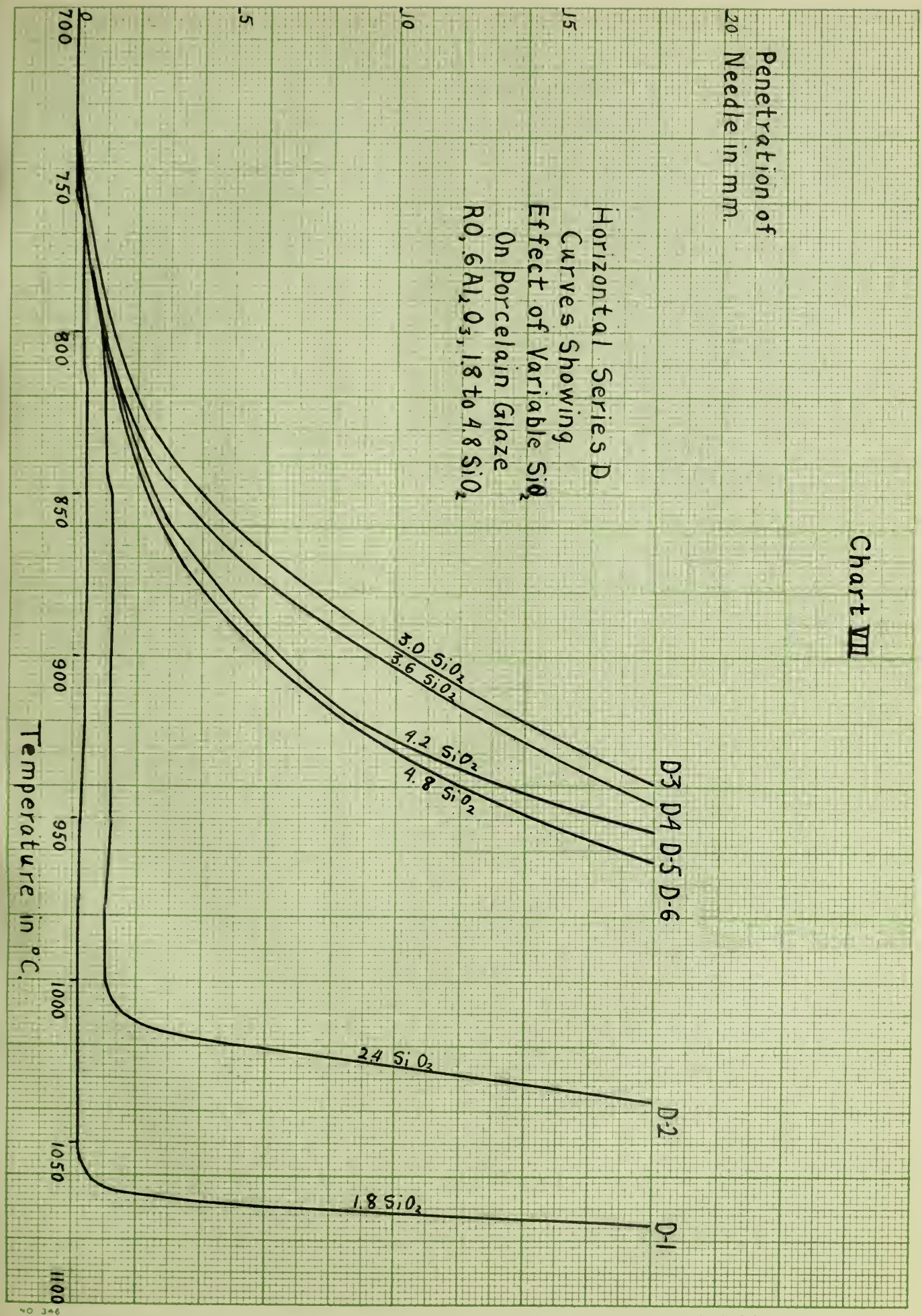
Chart IV.



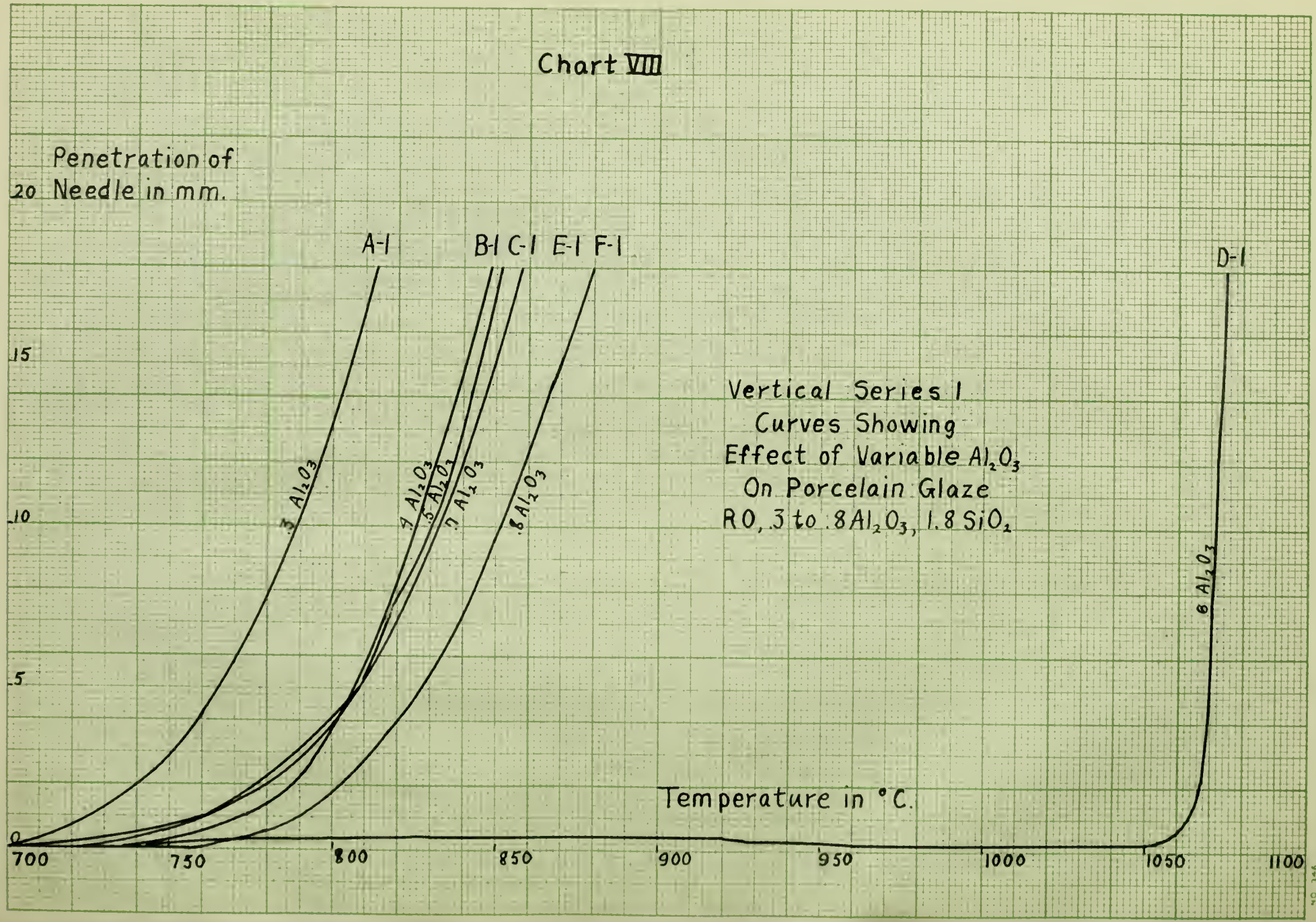
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Chart V
Penetration of Needle in mm.
20
15
10
5
0
B-1
B-2
B-3
B-4
B-5
B-6
1.8 SiO2
2.4 SiO2
3.0 SiO2
3.6 SiO2
4.2 SiO2
4.8 SiO2
Horizontal Series B
Curves Showing
Effect of Variable SiO2
On Porcelain Glaze
RO, .4 Al2O3, 1.8 to 4.8 SiO2
Temperature in °C.
700
750
800
850
900
950
1000
1050
1100


Chart VI
Penetration of
20 Needle in mm.
15
10
5
0
C-1
C-2
C-3
C-4
C-5
C-6
1.8 SiO2
2.4 SiO2
3.0 SiO2
3.6 SiO2
4.2 SiO2
4.8 SiO2
Horizontal Series C
Curves Showing
Effect of Variable SiO2
On Porcelain Glaze
RO, .5 Al2O3, 1.8 to 4.8 SiO2
Temperature in °C.
700
750
800
850
900
950
1000
1050
1100



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Chart VIII
Penetration of Needle in mm.
20
15
10
5
0
A-1
B-1
C-1
E-1
F-1
D-1
.3 Al2O3
.5 Al2O3
.7 Al2O3
.8 Al2O3
6 Al2O3
Vertical Series I
Curves Showing
Effect of Variable Al2O3
On Porcelain Glaze
RO, .3 to .8 Al2O3, 1.8 SiO2
Temperature in °C.
700
750
800
850
900
950
1000
1050
1100

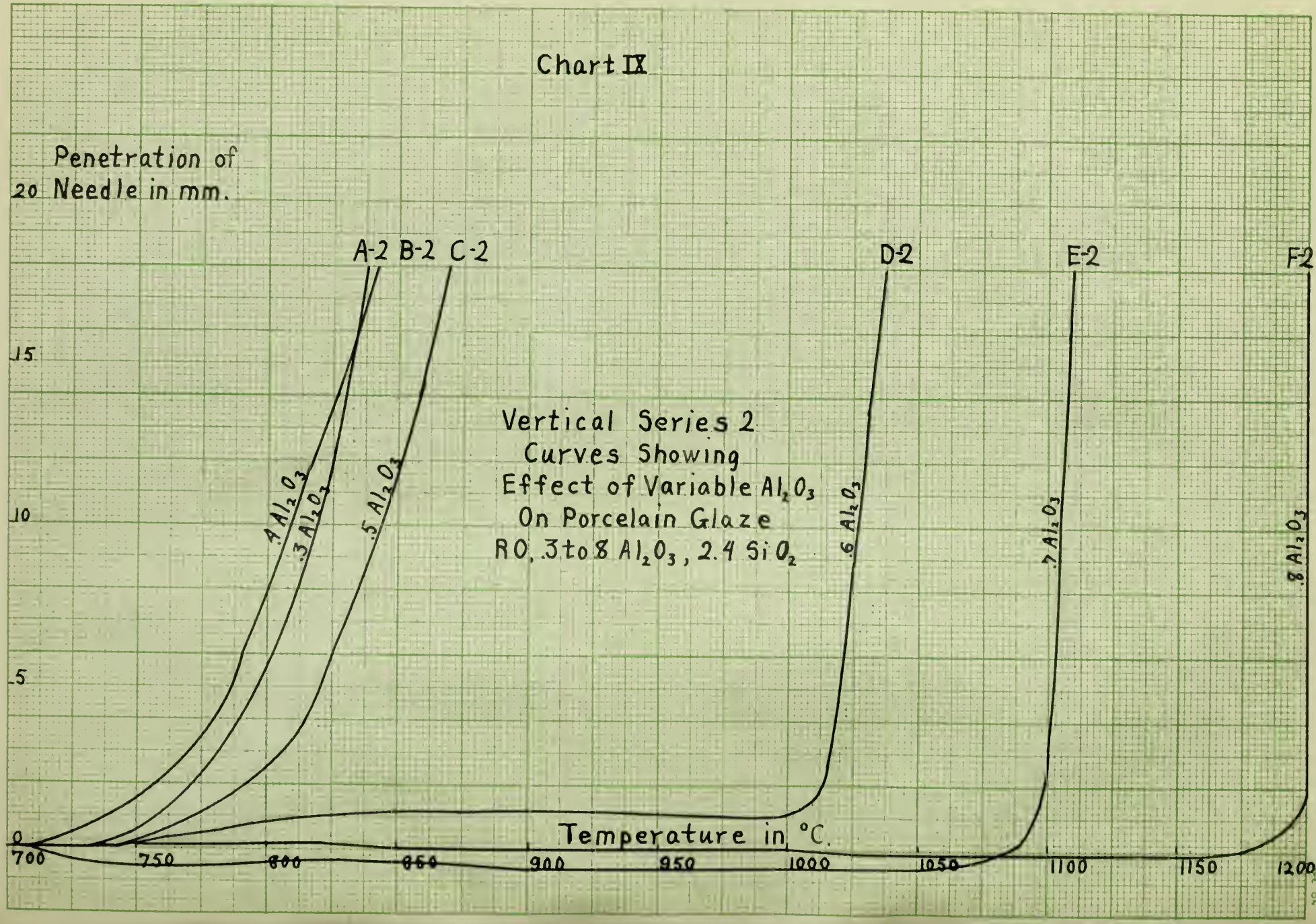
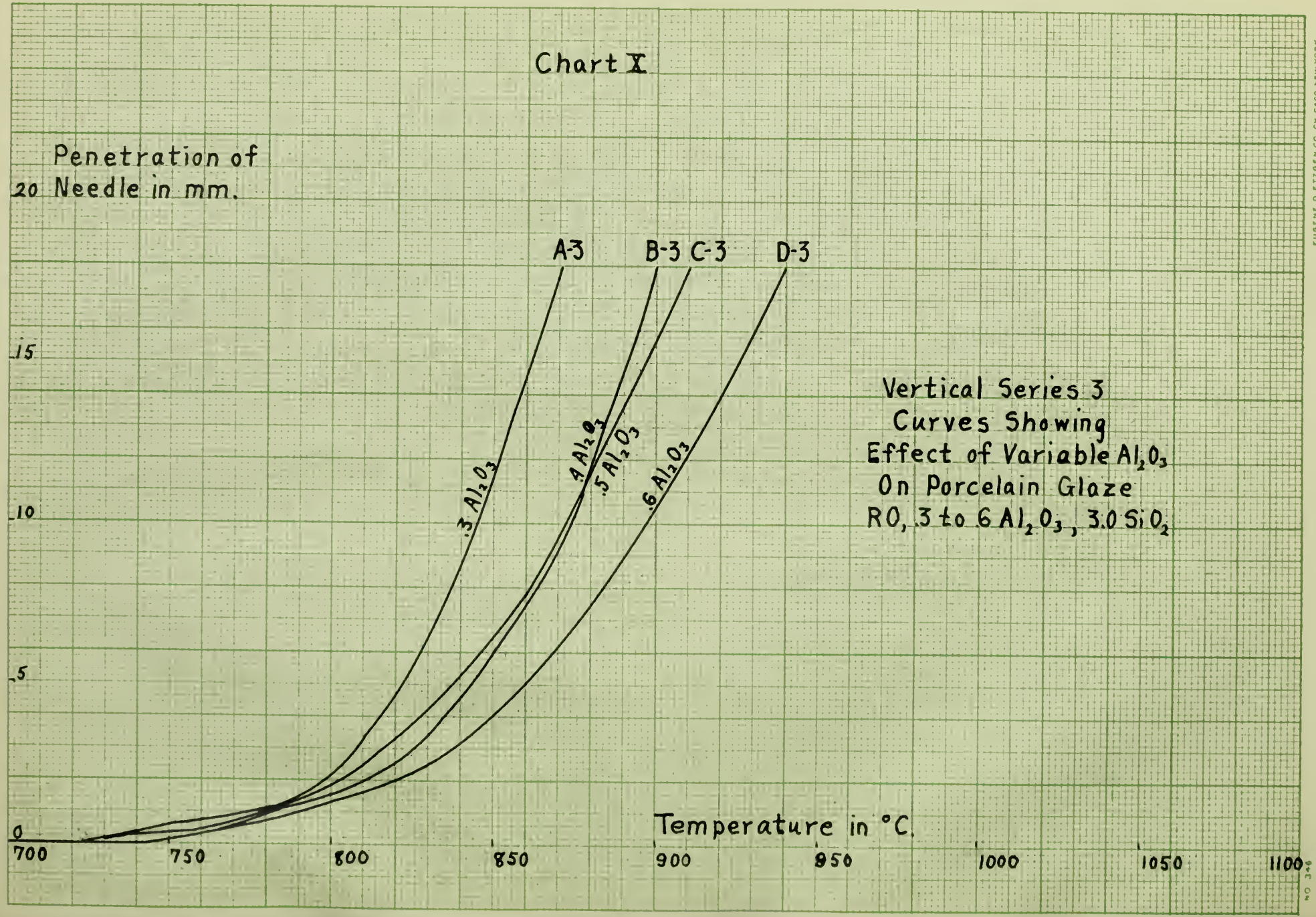
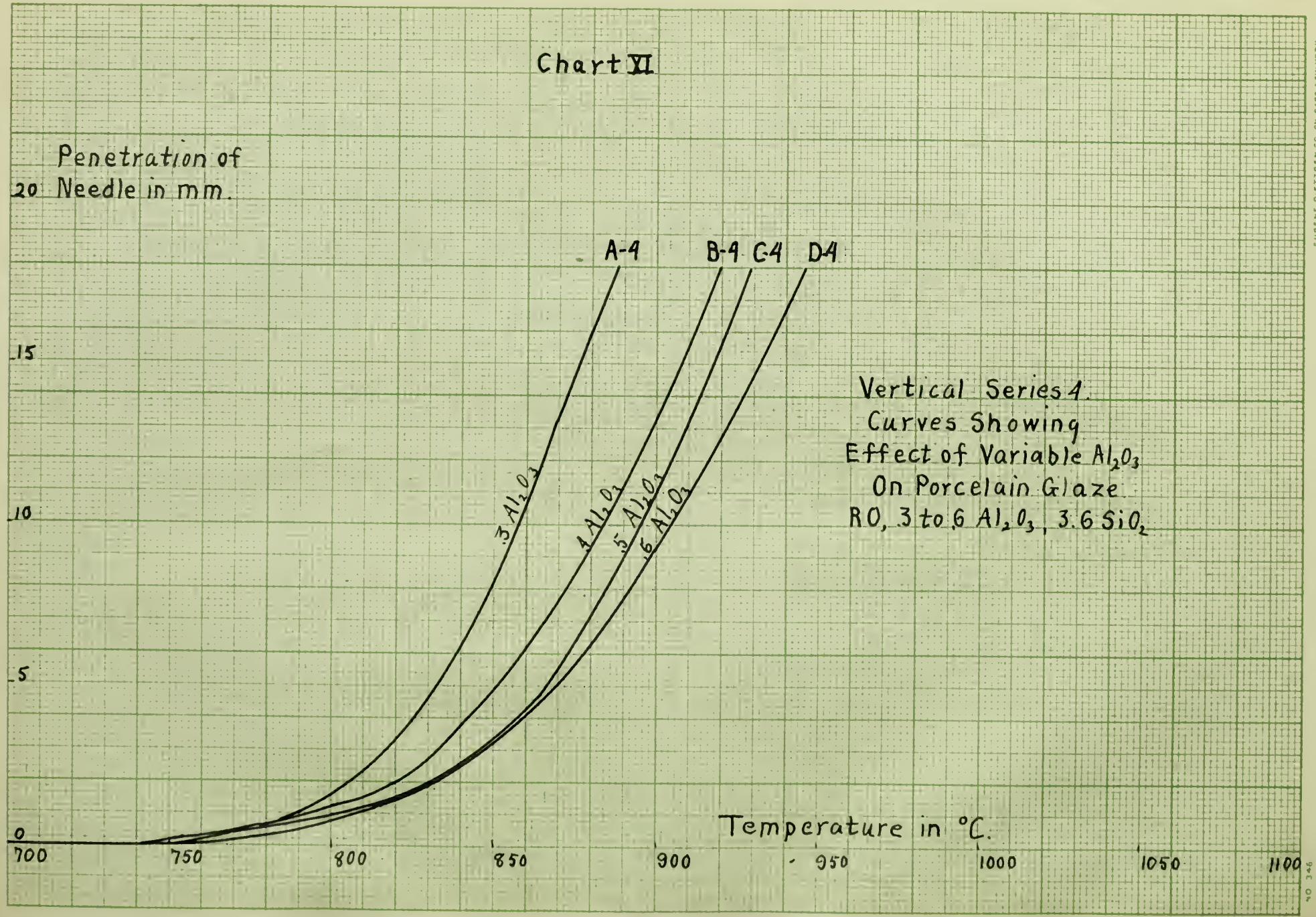

Chart IX
Penetration of
20 Needle in mm.
A-2 B-2 C-2
D-2
E-2
F-2
15
10
5
0
.4 Al2O3
.3 Al2O3
.5 Al2O3
.6 Al2O3
.7 Al2O3
.8 Al2O3
Vertical Series 2
Curves Showing
Effect of Variable Al2O3
On Porcelain Glaze
RO, .3 to 8 Al2O3, 2.4 SiO2
Temperature in °C.
700
750
800
850
900
950
1000
1050
1100
1150
1200

Chart X


Penetration of Needle in mm.
20
15
10
5
0
A-3
B-3
C-3
D-3
.3 Al_2O_3
.4 Al_2O_3
.5 Al_2O_3
.6 Al_2O_3
Vertical Series 3
Curves Showing
Effect of Variable Al_2O_3
On Porcelain Glaze
RO, .3 to .6 Al_2O_3, 3.0 SiO_2
Temperature in °C.
700
750
800
850
900
950
1000
1050
1100

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Chart XI


Penetration of Needle in mm.
20
15
10
5
0
A-4
B-4
C-4
D-4
.3 Al_2O_3
.4 Al_2O_3
.5 Al_2O_3
.6 Al_2O_3
Vertical Series 4.
Curves Showing
Effect of Variable Al_2O_3
On Porcelain Glaze
RO, .3 to .6 Al_2O_3, 3.6 SiO_2
Temperature in °C.
700
750
800
850
900
950
1000
1050
1100

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Chart XII

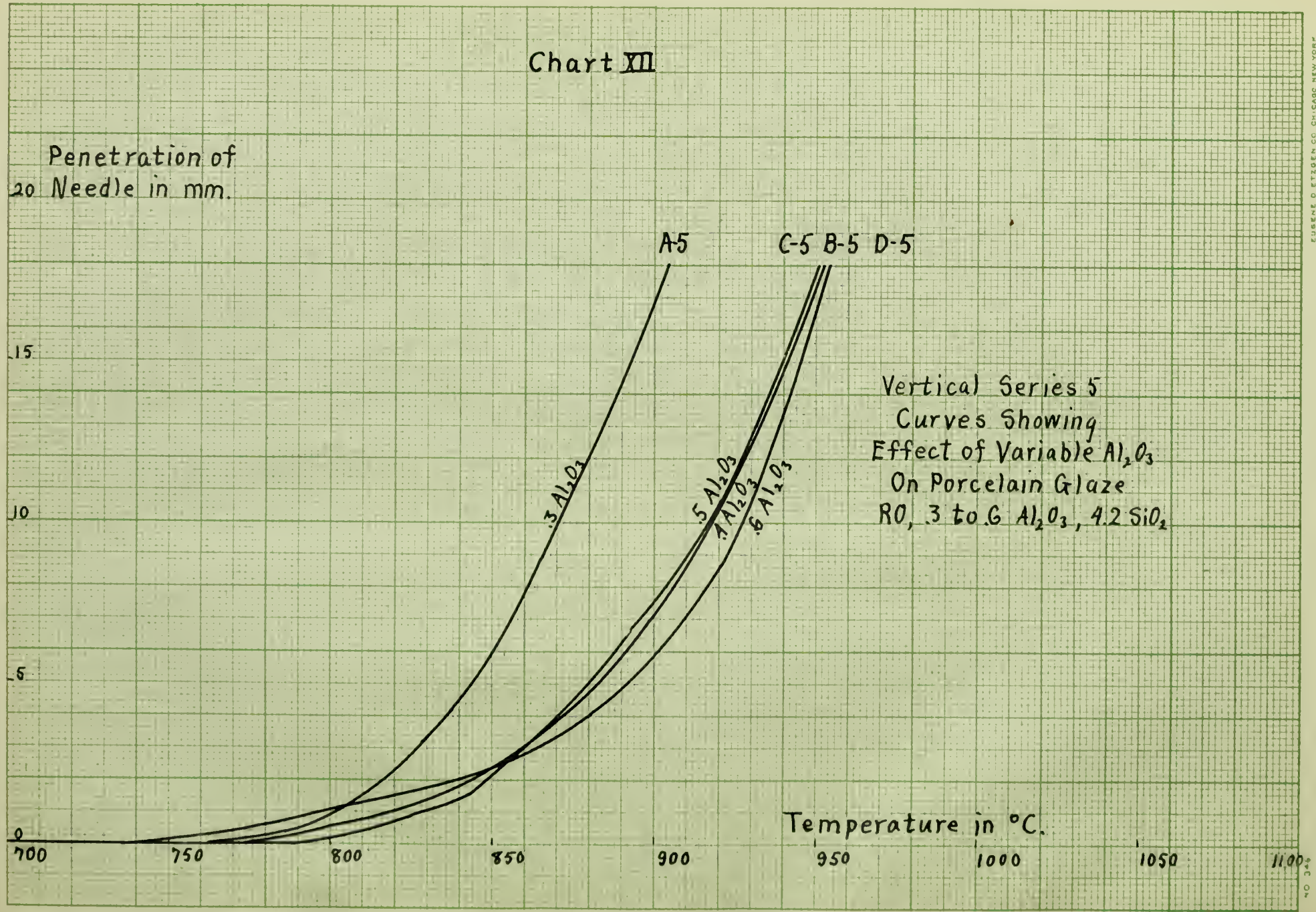
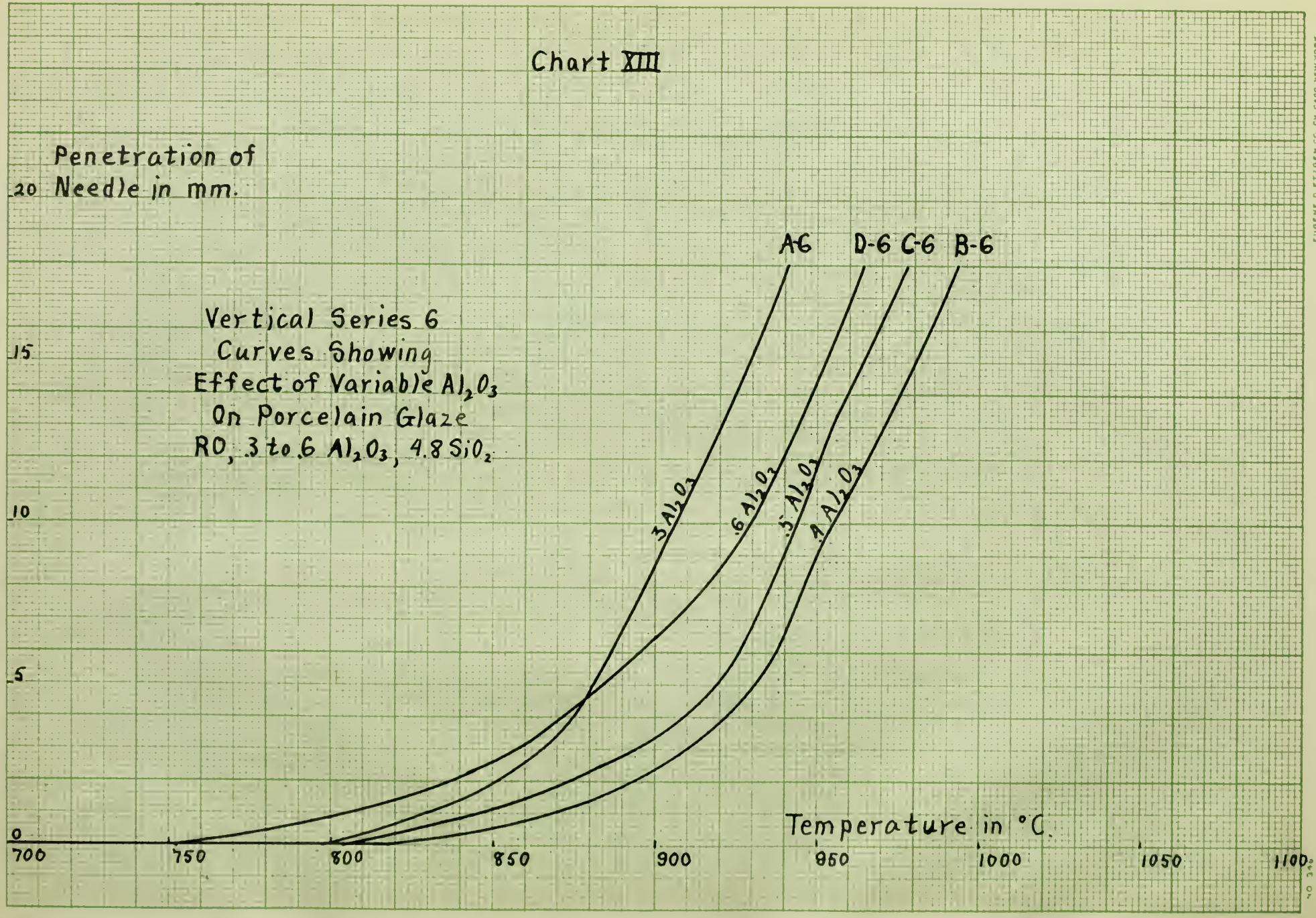
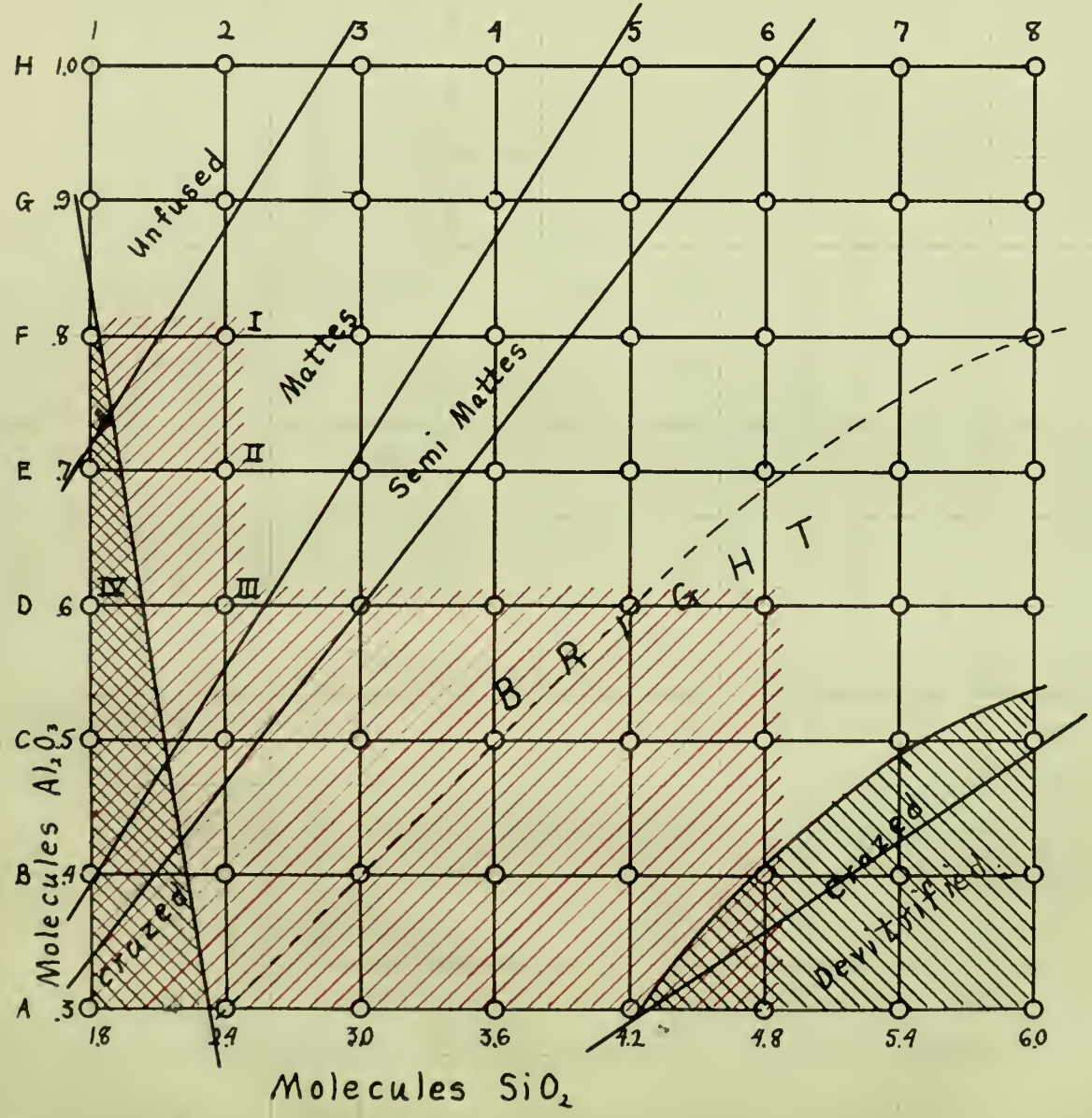

Penetration of
20 Needle in mm.
15
10
5
0
A-5
C-5 B-5 D-5
.3 Al_2O_3
.5 Al_2O_3
.4 Al_2O_3
.6 Al_2O_3
Vertical Series 5
Curves Showing
Effect of Variable Al_2O_3
On Porcelain Glaze
RO, .3 to .6 Al_2O_3, 4.2 SiO_2
Temperature in °C.
700
750
800
850
900
950
1000
1050
1100

Chart XIII


Penetration of Needle in mm.
20
15
10
5
0
Vertical Series 6
Curves Showing
Effect of Variable Al_2O_3
On Porcelain Glaze
RO, .3 to .6 Al_2O_3, 4.8 SiO_2
A-6
D-6
C-6
B-6
.3 Al_2O_3
.6 Al_2O_3
.5 Al_2O_3
.4 Al_2O_3
Temperature in °C.
700
750
800
850
900
950
1000
1050
1100

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Chart XIV



Part of field covered by Stull (Trans. Am. Cer. Soc. Vol. XIV, P 64.) Portion crosshatched in red, covered by writer I, II, III, IV = matte glazes giving high softening point and very short viscosity range.

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- Discussion of Results -

Charts IV to VII show the effect of variable silica with constant RO and Al_2O_3. Charts VIII to XIII show the effect of variable Al_2O_3 with constant RO and SiO_2. The curves show that increase of SiO_2 tends to raise the softening temperature of the glaze, while increase of Al_2O_3 has little effect upon the softening point, but tends to increase the range of viscosity of the glaze.

In the horizontal series with .3 Al_2O_3, A-1, containing 1.8 SiO_2, begins to soften at 700°C., and at 815°C. the platinum needle has penetrated 18 mm.; A-6, containing 4.8 SiO_2, begins to soften at 800°C., and the platinum needle has penetrated 18 mm. at 945°C. In the vertical series with 1.8 SiO_2, A-1, containing .3 Al_2O_3, softens at 700°C., and at 815°C. the needle has penetrated 18 mm.; E-1, containing .7 Al_2O_3, begins to soften at 725°C., and the needle has penetrated 18 mm. at 858°C.

The lines on Charts IV to VII show that softening begins at different points, but proceeds along lines nearly parallel thereafter; while those on Charts VIII to XIII indicate that softening begins at about the same point, but proceeds along lines which spread out fan shaped. This shows that the general tendency is for increase in Al_2O_3 to increase the range of viscosity, and for increase in SiO_2 to raise the temperature of the softening point without increasing the viscous range materially.

The curve for D-1 shows an abrupt change in the effect of alumina and silica. The softening point of this glaze does

not occur until 1050°C. is reached. From this temperature on, the viscosity drops suddenly, showing the range of viscosity to be very short. D-2 behaves in a similar manner, except that the softening point is at 1000°C., and the range of viscosity is slightly longer. E-2 and F-2 are two more glazes which give similar results. F-2 does not begin to soften until 1175°C. is reached. At 1200°C. the viscosity also drops suddenly. From these results it appears that there is a line passing thru D-1, D-2, E-2, and F-2 towards the upper left hand corner of the field, along which the softening point is high, and the range of viscosity short, and at each side of which the softening points are lower and the viscosity ranges longer. Looking at Chart XIV, it is observed that the glazes along this line are all matts. The bright glazes, being nothing more than undercooled solutions or congealed fluids, have no definite melting points, but softening intervals instead. The matt glazes, being crystalline aggregates, melt at more definite temperatures. The high temperature of softening and the short range of viscosity of these matt glazes may be due to the predominating crystalline substances having melting points very close together, giving a more or less "melting point effect."

The foregoing work indicates that the increase in Al_2O_3 with constant SiO_2 in the clear glazes (undercooled solutions) does not materially change the temperature at which softening begins, as indicated by the penetrating needle, but does decrease the rate of change of viscosity with change of temperature.

On the other hand, increase in SiO_2 with constant Al_2O_3

in the clear glazes materially raises the temperature at which softening begins, but does not materially affect the rate of viscosity change.

The temperature at which softening begins and the rate of viscosity change have important bearings on the sensitiveness of Seger cones and other similar pyroscopes. In the Seger cone series, the Al_2O_3 and SiO_2 increase in the molecular proportion of 1 to 10 from cones 5 to 27 inclusive. The result is a combined influence of both rise in softening temperature and prolongation of viscosity; therefore, the higher cones in the Seger series are not so sensitive as are the lower ones.

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